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RE: Application Serial No.: 09/830,849
Applicants: Takuji NOMURA, et al.
Filing Date: July 31, 2001
For: OPTICAL HEAD DEVICE
Group Art Unit: 2651
Examiner: GIESY, ADAM

SIR:

Attached hereto for filing are the following papers:

DECLARATION
JAPANESE PATENT APPLICATION NO. JP11-249285
(W/ ENGLISH TRANSLATION)

Our credit card payment form in the amount of **$0.00** is attached covering any required fees. In the event any variance exists between the amount enclosed and the Patent Office charges for filing the above-noted documents, including any fees required under 37 C.F.R 1.136 for any necessary Extension of Time to make the filing of the attached documents timely, please charge or credit the difference to our Deposit Account No. 15-0030. Further, if these papers are not considered timely filed, then a petition is hereby made under 37 C.F.R. 1.136 for the necessary extension of time. A duplicate copy of this sheet is enclosed.

Respectfully submitted,

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IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF:	:	
TAKUJI NOMURA ET AL	:	EXAMINER: GIESY, ADAM
SERIAL NO.: 09/830,849	:	
FILED: July 31, 2001	:	GROUP ART UNIT: 2651
FOR: OPTICAL HEAD	:	
	:	

DECLARATION

COMMISSIONER FOR PATENTS
ALEXANDRIA, VIRGINIA 22313

SIR:

Now comes TOSHIHARU OGAWA who deposes and says that:

That my name is TOSHIHARU OGAWA;

That my address is 6-3, Mure 1-chome, Mitaka-shi, Tokyo, Japan;

That I know well both the English and Japanese languages;

That the attached English language translation is true and correct translation of Japanese Patent Application No. JP11-249285 filed on September 2, 1999 to the best of my knowledge and belief;

I hereby declare further that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

FURTHER DEPONENT SAITH NOT.

October 4, 2005
Date

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(F2000-071)

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Application Number:	Patent Application JP11/249285
Applicant:	Asahi Glass Company, Limited

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【TITLE OF THE INVENTION】

OPTICAL HEAD DEVICE

【SCOPE OF THE CLAIM(S)】

【Claim 1】

An optical head device comprising a light source, an objective lens for converging outgoing light from the light source on an optical recording medium, a phase correcting element provided between the light source and the objective lens to change a wave front of the outgoing light, and a control voltage generator for outputting a voltage for changing the wave front to the phase correcting element, characterized in that the phase correcting element includes an anisotropic optical medium sandwiched between a pair of substrates, at least one of the substrates being transparent, the paired substrates have surfaces provided with electrodes for voltage application to the anisotropic optical medium, and the electrode on at least one of the substrates has a plurality of power supply electrodes provided thereon at different positions, thereby providing different voltages to the plural power supply electrodes.

【Claim 2】

The optical head device according to Claim 1, wherein the electrodes have a sheet resistance of not less than 100 Ω/□.

【Claim 3】

The optical head device according to Claims 1 or 2, wherein the anisotropic optical medium is a liquid crystal.

【Claim 4】

The optical head device according to Claim 1, 2 or 3, wherein only one of the paired substrates is a transparent substrate.

【DETAILED DESCRIPTION OF THE INVENTION】

【Technical Field to which the Invention Belongs】

The present invention relates to an optical head device, which carries out recording and reproducing of an optical recording medium, such as an optical disc.

【Prior Art】

Since a DVD as an optical disc has digital information recorded thereon in a high density in comparison with a CD as another optical disc, an optical head device for reproducing DVDs has the wavelength of a light source set at 650 nm or 635 nm shorter than 780 nm for CDs or the numerical aperture (NA) of an objective lens set at 0.6 greater than 0.45 for CDs, decreasing the spot size where the light converges on an optical disc surface.

In addition, it has been proposed that the wavelength of the light source be set about 400 nm and the NA be set at not less than 0.6 to obtain a greater recording density in the next generation of optical

recording. However, a decrease in the wavelength of the light source or an increase in the NA of the objective lens causes an allowable amount in tilt caused by inclination of an optical disc surface with respect to a direction perpendicular to the optical axis or an allowable amount in thickness variations of an optical disc to decrease.

The reason why these allowable amounts decrease is that the generation of coma aberration for tilted optical discs or the generation of spherical aberration for thickness variations of optical discs degrades the light convergence properties of an optical head device to make reading of signals difficult. There have been proposed several methods for expanding the allowable amounts of optical head devices with respect to tilted optical discs or the thickness variations in case of high density recording.

One of the methods is one wherein the actuator for an objective lens which is usually movable in two axial directions of a tangential direction and a radial direction of an optical disc has an axis for inclination added therein to incline the objective lens in response to a detected tilt angle. However, this addition method creates problems in that the spherical aberration can not be corrected and the structure of the actuator is complicated, for instance.

Another method is one wherein a phase correcting

element provided between an objective lens and a light source corrects spherical aberration. This correction method can expand the allowable amount in tilts or thickness variations of optical discs only by incorporation of the element into an optical head device without providing the actuator with significant modifications.

For example, there is JP-A-1020263 directed to the correction method wherein a phase correcting element is utilized to correct the tilt of optical discs. This is a method wherein voltages are applied to divided electrodes that are separately provided on each of a pair of substrates with a birefringent material, such as a liquid crystal, forming a phase correcting element sandwiched therewith, the substantial refractive index of the birefringent material is changed in response to the tilt angle of an optical disc, and the phase (wave front) change of transmitted light caused by the change in the refractive index corrects the coma aberration caused by the tilt of the optical disc.

【Problems that the Invention is to Solve】

However, the conventional phase correcting element requires that the electrodes on the phase correcting element be divided into plural segments, and the respective divided segments have different voltages as different control signals applied thereto in order to change the wave front of outgoing light from the light

source to correct wave front aberration. For this reason, many electrodes, wires and external signal sources (power sources) are needed to obtain a desired form of wave front, creating problem in that the structure of the element is complicated, and the use of many external signal sources (power sources) makes the device troublesome. Additionally, it is difficult to provide a continuous change with a single electrode since the variation in the wave front is even on that electrode. Further, the regions between divided electrodes could cause a decrease in transmission rate of light due to, e.g., light scattering since no external signal can be applied to the regions.

【Means of Solving the Problems】

The present invention is provided to solve these problems and provides an optical head device comprising a light source, an objective lens for converging outgoing light from the light source on an optical recording medium, a phase correcting element provided between the light source and the objective lens to change a wave front of the outgoing light, and a control voltage generator for outputting a voltage for changing the wave front to the phase correcting element, characterized in that the phase correcting element includes an anisotropic optical medium sandwiched between a pair of substrates, at least one of the substrates being transparent, the paired substrates have surfaces provided with electrodes

for voltage application to the anisotropic optical medium, and the electrode on at least one of the substrates has a plurality of power supply electrodes provided thereon at different positions, thereby providing different voltages to the plural power supply electrodes.

The present invention also provides an optical head device, wherein the electrodes have a sheet resistance of not less than 100 Ω/□.

The present invention also provides an optical head device, wherein the anisotropic optical medium is a liquid crystal.

The present invention also provides an optical head device, wherein only one of the paired substrates is a transparent substrate.

【Mode of Carrying out the Invention】

Fig. 1 is shown an example of the principle and structure of the optical head device according to the present invention. The optical head device shown in Fig. 1 is one that reproduces information recorded on an optical disc 8, such as a CD and a DVD, wherein outgoing light from a light source 1, such as a semiconductor laser, is made into collimated light by a collimating lens 3 after passing through a polarized beam splitter 2, such as a hologram type one, passes through a phase correcting element 4, is reflected in a 90° direction by an upwarding guiding mirror 11, passes through a quarter-wave plate 5, and is converged on the optical disc 8 by

an objective lens 6 provided in an actuator 7. In this example, both paired substrates forming the phase correcting element 4 are transparent.

The converged light is reflected by the optical disc 8, sequentially passes the objective lens 6, the quarter-wave plate 5, the upwarding guiding mirror 11, the phase correcting element 4 and the collimating lens 3 in the reverse direction, and then is diffracted by the polarized beam splitter 2 to enter a photo-detector 9. When the outgoing light from the semiconductor laser 1 is reflected by the optical disc 8, the reflected light is amplitude-modulated by information recorded on the optical disc surface, and the recorded information can be read as light intensity signals by the photo-detector 9.

The polarized beam splitter 2 includes, e.g., a polarized hologram and intensively diffracts light with a polarized component in an anisotropic direction (a direction having different refractive indices) to direct the light to the photo-detector 9. A phase correcting element control circuit 10 as a control voltage generator outputs a voltage to the phase correcting element 4 so that, for example, the intensity of reproduced signals from the optical disc obtained by the photo-detector 9 are optimized. The voltage outputted from the phase correcting element control circuit 10 is a voltage in response to an amount of the tilt of the optical disc or an amount of the shift of the objective lens, which is a

substantially variable voltage applied to an electrode of the phase correcting element 4.

The upwarding guiding mirror 11 works to reflect the outgoing light from the semiconductor laser 1 in about a 90° direction to direct the light into the optical disc, and the mirror is an optical element, which is preferably used to reduce the thickness of the optical head device (in a direction perpendicular to the surface of the optical disc 8). Normally, an optical element with a highly reflective film, such as aluminum, deposited on a glass surface is used as the mirror.

Although the mirror 11 is utilized to change the light path of the outgoing light from the semiconductor laser 1 in Fig. 1, the direction of the outgoing light from the semiconductor laser 1 may be originally set to extend perpendicularly to the surface of the optical disc 8 without using the mirror 11.

An optical crystal, such as lithium niobate, or a liquid crystal can be used as the anisotropic optical medium. It is preferable that a liquid crystal is used as the anisotropic optical medium since it is possible to control a substantial refractive index easily by a low voltage, such as about 6V, and continuously in response to the magnitude of a voltage. A liquid crystal is preferable since it has good productivity in comparison with, e.g., an optical crystal, such as lithium niobate. From this viewpoint, a case wherein a liquid crystal

material is used as the anisotropic optical medium will be explained.

A nematic liquid crystal, which is used for display applications, is suited as the liquid crystal material to be used, and the nematic liquid crystal may be twisted by addition of a chiral agent.

As the material of the substrates to be used, glass, acrylic resin, epoxy resin, vinyl chloride resin and the like may be used, and glass substrates are preferable in terms of durability and other factors. From this viewpoint, a case wherein glass is used as the substrate material will be explained.

Now, the structure of the phase correcting element used in the present invention will be described, referring to Fig. 2. Glass substrates 21a, 21b are bonded by seals 22 with, e.g., epoxy resin contained as a main component to provide a liquid crystal cell. The seals 22 include a spacer made of, e.g., glass and an electrically conductive spacer having, e.g., gold coated on a surface of, e.g., resin. The glass substrate 21a has an electrode 24a, an insulating layer 25 with silica and another material contained as main components, and an alignment layer 26 coated on an inner surface thereof in this order from the inner surface, and the glass substrate 21b has an electrode 24b, an insulating layer 25 with silica and another material contained as main components, and an alignment layer 26 coated on an inner

surface thereof in this order from the inner surface. The liquid cell may have an outer surface coated with an anti-reflection film.

The electrode 24a has a wiring pattern that has an electrode lead 27 connected with the phase correcting element control circuit through a connecting wire. The electrode 24b is electrically connected to the electrode 24a on the glass substrate 21a through the conductive spacers having gold or another material coated thereon as explained, and the electrode 24b can be connected to the phase correcting element control circuit at the electrode lead 27 through the connecting wire. Although it is not shown in Fig. 2 that the electrode 24b and the electrode 24a contact the seals 22, both electrodes contact the seals in a direction in parallel with the drawing sheet to be electrically connected through conductive spacers. The liquid crystal cell has liquid crystals 23 filled therein, and liquid crystal molecules 28 shown in Fig. 2 are in a homogeneous alignment state with single alignment.

In accordance with the present invention, at least one of the electrode 24a and the electrode 24b has two or more of power supply electrodes provided at different positions on a surface thereof to supply different voltages to the positions. In other words, two or more supply portions are provided in case of the provision of the supply portions on a single electrode, and two or

more power supply electrodes are provided on the respective electrodes in case of the provision of the power supply electrodes on both electrodes (totally four or more power supply electrodes).

As the material for the alignment layers are preferable ones with the liquid crystal molecules 28 having a pretilt angle between 2°-10° and acceptable ones with a polyimide film subjected to rubbing treatment in right-hand and left-hand directions in parallel with the drawing sheet of Fig. 2 or with a silica layer obliquely deposited. An increase in the difference between the ordinary refractive index and the extraordinary refractive index of a liquid crystal and a decrease in the spacing of the liquid cell are preferable in terms of good response. However, it is preferable that the difference between the ordinary refractive index and the extraordinary refractive index is 0.1-0.2 and that the spacing is about 2-5 μm since fabrication of the liquid cell becomes more difficult as the spacing becomes smaller.

In the case of the optical head device shown in Fig. 1, the material for the electrodes 24a, 24b preferably has a high transmission rate since the paired substrates are both transparent and since light passes through the phase correcting element 4, and a transparent and electrically conductive film, such as ITO film, may be used. In this case, the phase correcting element 4 is

used as a transmission element.

However, when only one of the paired substrates is a transparent substrate, either one of the electrodes 24a, 24b can be fabricated from a material having a high reflectivity, such as aluminum and chromium, to use the phase correcting element 4 as a reflection element. In this case, the phase correcting element 4 in place of the upwarding guiding mirror 11 of Fig. 1 can be located at the position of the mirror. If the electrode on the side with the light entering first (e.g., the electrode 24a) is a transparent electrode having a high transmission rate, and the other electrode (e.g., the electrode 24b) is an electrode having a high reflectivity, the light having entered the phase correcting element 4 passes through the transparent electrode 24a and the liquid crystal, is reflected by the electrode 24b and is directed to the optical disc 8, passing through the liquid crystals and the transparent electrode 24a.

When a reflection element is used as the phase correcting element 4 as stated earlier, i.e., when one of the paired substrates forming the phase correcting element is a transparent substrate, the number of parts can decrease and the thickness of the optical head device can be made thinner since the upwarding guiding mirror of Fig. 1 can be replaced by the phase correcting element 4. In this case, the spacing of the liquid crystal cell (the thickness of the liquid crystal layers in the liquid

crystal cell) may be differentiated from the case of a transmission element since the light entering the phase correcting element 4 passes through the liquid crystals 23 twice at an angle of about 45°.

Now, the power supply electrodes for voltage supply, which are provided on the electrode of a substrate forming the phase correcting element and sandwiching the anisotropic optical medium in the present inventions, will be explained.

In the present invention, each of the paired substrates has each of the electrodes provided thereon, totally providing the two electrodes. It is preferable that the respective electrodes are provided on the opposed surfaces of the paired substrates. It is acceptable that one of the two electrodes may have two or more power supply electrodes provided at different positions thereon, and the other electrode may have a single power supply electrode, or that the two respective electrodes may have two or more power supply electrodes provided at different positions thereon. In the case wherein each of the electrodes on the two surfaces has two or more power supply electrodes provided thereon, the power supply electrodes may be located in confronted fashion or in unconfronted fashion between both electrodes.

When voltages are applied to the anisotropic optical medium, the respective power supply electrodes work as

stated below.

When only one of the electrodes has two or more power supply electrodes provided thereon, the electrode having a single power supply electrode serves as a common electrode C (equal potential), different voltages are supplied between the two or more power supply electrodes (S_1, S_2, S_3...) on the one electrode and the common electrode, i.e., between C-S_1, C-S_2, C-S_3....

When each of the electrodes has two or more power supply electrodes provided thereon, and when the power supply electrodes are located in confronted fashion between both electrodes, different voltages are supplied between the two or more power supply electrodes (S_1, S_2, S_3...) on one of the electrode and the two or more power supply electrodes (S_1', S_2', S_3'...) on the other electrode, i.e., between S_1'-S_1, S_2'-S_2, S_3'-S_3....

When each of the electrodes has two or more power supply electrodes provided thereon, and when the power supply electrodes are located in unconfronted fashion and deviated each other between both electrodes, different voltages are supplied between the two or more power supply electrodes (S_1, S_2, S_3...) on one of the electrode and the two or more power supply electrodes (T_1, T_2, T_3...) on the other electrode, i.e., between T_1-S_1, T_2-S_2, T_3-S_3....

In case of the provision of the electrodes in unconfronted fashion, the shape or the size of the power

supply electrodes may be different from each other between T_1 and S_1, T_2 and S_2, T_3 and S_3, and another pair, and a suitable shape or a suitable size may be selected according to purposes. In case of the provision of the electrodes in confronted fashion as well, the shape or the size of the power supply electrodes may be different from each other as required.

The provision of the power supply electrodes at about 10 locations on an electrode can change the wave front at a sufficient amount, though the number of the power supply electrodes varies according to their purpose or shape.

Although metal materials, such as copper, gold, aluminum and chromium, are preferable as the power supply electrode material in terms of electrical conductivity and durability, materials except for metal can be used as long as their specific resistance is about 10^{-8}-10^{-7} $\Omega \cdot m$ at room temperature.

On the other hand, as the electrode material, a transparent conductive film, such as an ITO film, is proper, and it is preferable that the ITO film has a higher sheet resistance, especially not less than 100 $\Omega/\square$. As the sheet resistance is higher, the potential between adjoining electrodes can have a continuously variable pattern in easier fashion.

Under the circumstances, although each of the power supply electrodes S_1, S_2, S_3... has an equal potential

therein in a case wherein two or more power supply electrodes are provided on only one of the electrodes and the two or more supply portions have different voltages supplied thereto, the potential between S_1 and S_2, for instance, has a continuously variable pattern due to the provision of the ITO film having a high resistance. The continuously variable state is also applied to a case wherein two or more power supply electrodes are provided on the two electrodes and different voltages are supplied.

It is preferable that the shape and the size of the power supply electrodes are varied according to circumstances as stated earlier. The shape and the size may be varied according to the kind of wave front aberration to be corrected or the shape of a wave front to be generated since changes in the wave front caused by the phase correcting element depend on the shape and the size of the power supply electrodes. Examples of the wave front aberration are coma aberration, spherical aberration, astigmatism and the like.

For example, in the case of comma aberration, it is preferable that an electrode has a central portion provided with a power supply electrode in a rectangular or linear shape and a peripheral portion provided with a power supply electrode in a shape similar to a peripheral portion of the electrode (e.g. an arced shape) in a normal case.

In the case of spherical aberration, it is

preferable that there are provided a plurality of power supply electrode in a concentric shape, wherein an increased number of the power supply electrodes provides a further desired potential distribution.

In the case of astigmatism, it is preferable that a plurality of power supply electrodes are radially provided so as to pass through a single point at a central portion of the electrode, wherein an increased number of the power supply electrodes provides a further desired potential distribution.

In addition, it is possible to correct wave front aberration including both coma aberration and spherical aberration, wherein there may be adopted measures, such as a combination of the linear power supply electrode and the concentric power supply electrodes stated earlier.

Since coma aberration, spherical aberration, astigmatism etc. as the wave front aberration is caused by the optical head device as a system, the phase correcting element according to the present invention can be incorporated into the optical head device to correct the wave front aberration effectively.

【Examples】

[EXAMPLE 1]

The optical head device according to this example includes a phase correcting element for correcting the coma aberration caused by a tilt of an optical disc, and the phase correcting element is characterized in that,

even if there is caused a shift in an object lens in a radial direction of the optical disc, the element can obtain a phase (wave front) distribution for proper correction without integrally driving the objective lens and the phase correcting element. The optical head device with the phase correcting element incorporated thereinto in this example is one shown in Fig. 1.

Fig. 3 shows the electrode pattern of the phase correcting element in this example, wherein the hatched portion indicates a transparent electrode 30 made of an ITO film as an electrode, and the thick lines indicate metal electrodes 31-36 as power supply electrodes. The metal electrodes 31-36 are connected to signal sources (not shown) outside the phase correcting element through metal wires 37 to be supplied with certain voltages by respective signals 1-6.

The metal electrodes 32-35 have a width of 100 μm and a length of 1.5 mm, and the metal electrodes 31 and 36 have a width of 100 μm and an arced length of 6 mm.

The electrode pattern was formed as follows. First, an ITO film was deposited on a glass substrate by use of a sputtering method, and then the ITO film was patterned by use of a photolithographic technique. In that time, the ITO film was left at portions for the metal electrodes, and the ITO film was removed at portions for the metal wires and their surroundings by etching to make the metal wires isolated from the transparent electrode

30. Next, the metal electrodes and the metal wires shown in Fig. 3 were provided by a lift-off method. The material used for the metal electrodes was aluminum.

By the way, a region shown in a dotted line in Fig. 3 indicates an effective pupil, through which a light ray passes when there is no shift in the objective lens, wherein the shape of the electrodes are prolonged by the amount of a shift in the objective lens along the shift direction (the right-hand and left-hand direction in this figure) of the objective lens.

Now, the reason why the phase correcting element of this example can be employed to correct the tilt of the optical disc effectively even if there is caused a shift in the objective lens will be explained. In Fig. 4 is shown wave front aberration (mainly coma aberration) that is a phase change caused when an optical disc having a thickness of 0.6 mm is tilted at an angle of 1° in an optical head device, where the objective lens has an NA of 0.6 and the light source has a wavelength of 0.6 μm. If the phase change by the phase correcting element has a reversed phase to the amount of the wave front aberration of Fig. 4, the wave front aberration caused by the tilted optical disc can be canceled.

The phase correcting element in this example provided a phase change to cancel the wave front aberration as follows:

First, Fig. 5 shows the phase change that was caused

by the phase correcting element when there was no shift in the lens. In Fig. 5, the phase change is shown in nm, the phase change was caused to have different magnitudes of 140 nm (a substantially rectangular portion) and -140 nm (a peripheral portion of the effective pupil) in opposite directions in a left half region for instance, and the curves between these portions indicate contour lines, each of which indicates about 47 nm in this figure.

In this example, a voltage of 1.5V was supplied to the metal electrode 31 of Fig. 3, a voltage of 2.7V was supplied to the metal electrodes 32, 33 of Fig. 3, a voltage of 1.9V was supplied to the metal electrode 34, 35 of Fig. 3, and a voltage of 3.2V was supplied to the metal electrode 36 of Fig. 3 when there was no shift in the lens. In this example, the electrode that was opposed to the electrode with the six power supply electrodes (the metal electrodes) comprises a transparent electrode and constantly is at a potential of 0V.

Since the transparent electrode 30 having a high resistance is electrically connected to the metal electrodes 31-36 having different potentials, the voltages vary according to locations, producing an uneven voltage distribution. Since the liquid crystal molecules in the phase correcting element have alignment directions changed by voltage application to cause variations in the alignment direction according to the uneven voltage distribution, the phase change $\delta n \cdot d$ of incident light

varies according to locations. In this explanation, d indicates the distance between the substrates of the liquid crystal cell, and δn indicates the substantial refractive index difference at each of points therein, which varies according to an applied voltage.

In this example, the phase change of Fig. 5, which was provided by supplying the voltages to the metal electrodes 31-36 as explained, canceled the wave front aberration of Fig. 4.

Next, a case wherein there was caused a shift in the lens in the right-hand direction of Fig. 3 will be explained. In Fig. 6 is shown the phase change that is provided by the phase correcting element to correct the wave front aberration (mainly the coma aberration) caused when the shift amount of the lens is 0.3 mm and the disc has a tilt angle of 1°. In this case, the signals 1-6 were set so that a voltage of 1.5V was supplied to the electrode 31, a voltage of 2.6V was supplied to the electrode 33, a voltage of 1.8V was supplied to the electrode 35, and a voltage of 2.7V was supplied to the electrode 36 though no voltage was not supplied to the electrode 32 or 34. The effective pupil on the phase correcting element shifts in the right-hand direction, following the shift in the lens. From this viewpoint, by supplying the voltages to the metal electrodes 36, 35 on the right side among the paired metal electrodes 32, 33 and the paired metal electrodes 34, 35, the wave front

aberration shown in Fig. 4 could be corrected since the position having the maximum magnitude in the phase change moved, following the shift of the lens.

Likewise, when there was caused a shift in the lens in the left-hand direction, the wave front aberration could be corrected as in the case in the right-hand direction since the signals 1-6 were set so that a voltage of 1.5V was supplied to the electrode 31, a voltage of 2.4V was supplied to the electrode 32, a voltage of 1.6V was supplied to the electrode 34, and a voltage of 2.7V was supplied to the electrode 36, though no voltage was supplied to the electrode 36 or 35.

The maximum value of the shift amount of the lens in this examples was 0.4 mm, and the distance between the metal electrodes 32 and 33, and the distance between the metal electrodes 34 and 35 were set at 0.6 mm to be able to correct the wave front aberration even if the shift amount of the lens had the maximum value. It is preferable that these distances are set at about 70-80% of the shift amount of the lens to be considered.

When the shift amount of the lens was larger or smaller than 0.3 mm, the voltages supplied to the metal electrodes 32-35 were properly modified to continuously correct the wave front aberration to the tilt of the optical disc and the shift of the lens.

Although the case wherein no voltage was supplied to the metal electrode 32 or 34 in the above-mentioned case

has been explained, a voltage intermediate between the voltages supplied to the metal electrodes 31 and 33 may be supplied to the metal electrode 32, and a voltage intermediate between the voltages supplied to the metal electrodes 35 and 36 may be supplied to the metal electrode 34, providing a phase change similar to Fig. 6.

[EXAMPLE 2]

The optical head device according to this examples includes a phase correcting element for correcting spherical aberration caused by variations in the thickness of an optical disc. When the thickness of an optical disc is deviated from a design value, the objective lens produces spherical aberration, lowering the reading accuracy of signals. The phase correcting element for correcting this spherical aberration was incorporated as the phase correcting element 4 of the optical head device of Fig. 1. However, the phase correcting element control circuit 10 was modified for the phase correcting element of this example.

The element structure of the phase correcting element of this example is the same as the one shown in Fig. 2, and only the electrode pattern is different as stated below. With regard to the production method and the structure material of the phase correcting element, the same ones as in the Example 1 were used. Now, the principle that the spherical aberration is corrected by the phase correcting element of this example may be

explained.

Fig. 7 is a view showing front aberration (spherical aberration) that is caused when an optical disc has a thickness made thicker than a design value of 0.6 mm by 0.03 mm in an optical system where an objective lens has a NA of 0.65 and a light source has a wavelength of 0.4 μm. When an optical disc has a thickness made thicker than a design value, the phase at an intermediate portion between a central portion and a peripheral portion of an effective pupil advances in comparison with the central portion and the peripheral portion, while when the optical disc has a thickness made thinner than the design value, the phase at the intermediate portion delays in comparison with the central portion and the peripheral portion. The electrode pattern of the phase correcting element in this example is shown in Fig. 8.

In Fig. 8, the hatched portion indicates a transparent electrode 80 made of an ITO film, and the thick lines indicate metal electrodes 81-83. The respective metal electrodes 81-83 are connected to different external signal sources through metal wires 84 to be supplied with certain voltages by respective signals 1-3. The material and the fabrication method of the electrode pattern are the same as the ones in the example 1, and portions of the transparent electrode 80 around a metal wiring portion thereof connected to the metal electrodes 82, 83 are removed by etching in this

example.

The metal electrodes 81 and 82 in Fig. 8 have an outer diameter of 4 mm and an outer diameter of 3 mm, respectively, and a width of 100 µm, and the metal electrode 83 has an outer diameter of 200 µm.

In order to use the phase correcting element to correct the spherical aberration that is caused by a thickness variation of 0.03 mm of the optical disc, a voltage of 2.3V was supplied to the metal electrodes 81, 83, and a voltage of 2.0V was supplied to the metal electrode 82. In this example as well, the electrode that was opposed to the electrode with the three power supply electrodes (the metal electrodes) comprises a transparent electrode and constantly is at a potential of 0V as in the Example 1.

Fig. 9 shows the phase change that was caused by the phase correcting element. In Fig. 9 as in Fig. 5, the phase change is shown in nm, a central portion of the circles and a peripheral portion have a phase change of 0 nm, and a region having a phase change of −100 nm is located in an intermediate portion. The plural circles in solid lines indicate contour lines, each of which indicates 20 nm in the region of −100 nm and about 30 nm outside the region.

The transparent electrode 80 produces a voltage distribution according to the voltages applied to the respective metal electrodes. The above-mentioned

explanation is also applicable, and the phase correcting element can produce the phase change in a concentric shape shown in Fig. 9 since the voltage distribution causes a substantial refractive index rate distribution in the liquid crystal.

On the other hand, when the thickness of a optical disc is thinner by 0.03 mm, a voltage of 2.0V may be supplied to the metal electrodes 81, 83, and a voltage of 2.3V is supplied to the metal electrode 82, correcting the spherical aberration wherein the positive and negative signs in Fig. 7 are reversed . Thus, the phase change caused by the phase correcting element also have a form wherein the positive and negative signs in Fig. 9 are reversed to cancel the spherical aberration. As explained, proper voltages can be supplied to the metal electrodes 81, 82, 83 to correct the spherical aberration of Fig. 7. Both metal electrodes 81, 83 may be coupled together and connected to a single power source since optical properties are not significantly effected even if an equal voltage is constantly supplied to the metal electrodes.

【Effects of the Invention】

As explained, the optical head device according to the present invention can effectively correct the wave front aberration caused by the tilt of an optical disc, a thickness variation thereof or another factor to obtain excellent signal light with noise minimized since two or

more supply portions can be provided on at least one of electrodes formed on the paired substrates forming the phase correcting element, producing a continuous phase (wave front) change in outgoing light from the light source by this phase correcting element.

In addition, even if a shift in the objective lens is caused in a radial direction of an optical recording medium, the wave front aberration (mainly the coma aberration) can be corrected without driving the phase correcting element integrally with the objective lens. In addition, the spherical aberration caused by the thickness variation in an optical disc can be corrected.

【Brief Explanation of the Drawings】

【Figure 1】

Schematic sectional view showing an example of the principle and structure of an optical head device according to the present invention.

【Figure 2】

Cross-sectional view showing an example of the phase correcting element according to the present invention.

【Figure 3】

Schematic plan view showing the electrode pattern of the phase correcting element according to a first Example.

【Figure 4】

Diagram showing wave front aberration, wherein a tilt angle of 1° is caused in an optical disc.

【Figure 5】

Diagram showing a phase change caused by the phase correcting element according to the first Example (when there is no lens shift).

【Figure 6】

Diagram showing a phase change caused by the phase correcting element according to the first Example (when there is a lens shift in the right-hand direction).

【Figure 7】

View showing spherical aberration, which is caused when an optical disc has a thickness variation of 0.03 mm.

【Figure 8】

Circuit diagram showing an example of the equivalent circuit of the phase correcting element of a second Example.

【Figure 9】

Diagram showing a phase change caused by the phase correcting element according to the second, a third or a fifth Example.

【Explanation of the Reference Numerals】

1: Semiconductor laser

2: Polarized beam splitter

3: Collimating lens

4: Phase correcting element

5: Quarter-wave plate

6: Object lens

7: Actuator

8: Optical disc

9: Photo-detector

10: Phase correcting element control circuit

21a, 21b: Glass substrate

22: Seal

23: Liquid crystal

24a, 24b: Electrode

25: Insulating layer

26: Alignment layer

27: Electrode lead

28: Liquid crystal molecule

30, 80: Transparent electrode

31-36: Metal electrode

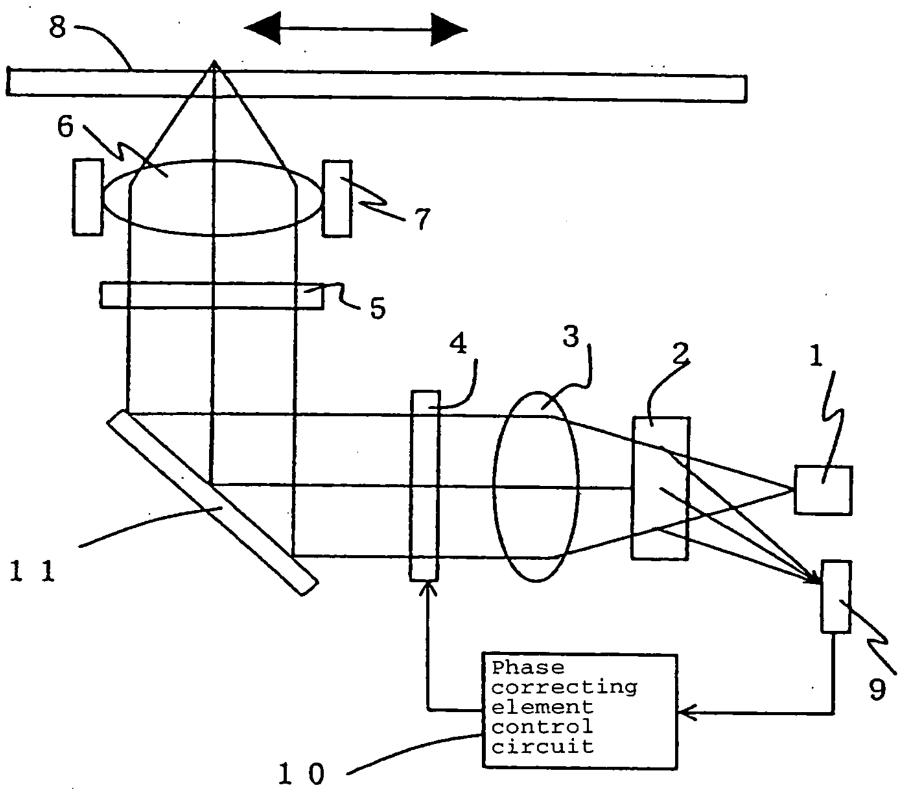
37: Metal wire

81-83: Metal electrode

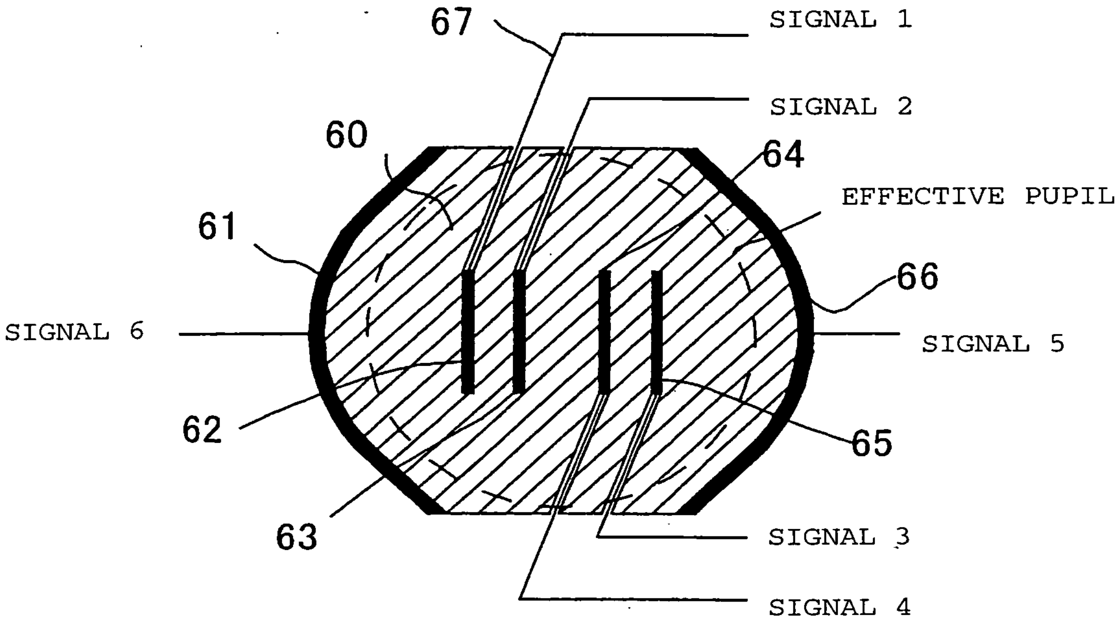
84: Metal wire

【TYPE OF DOCUMENT】 DRAWING

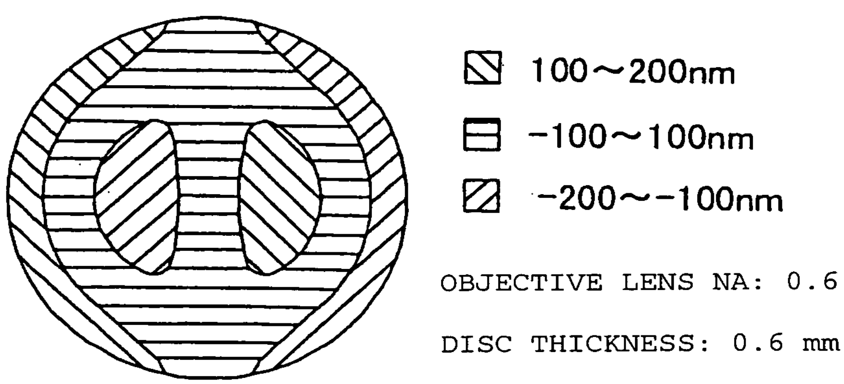
【Fig. 1】



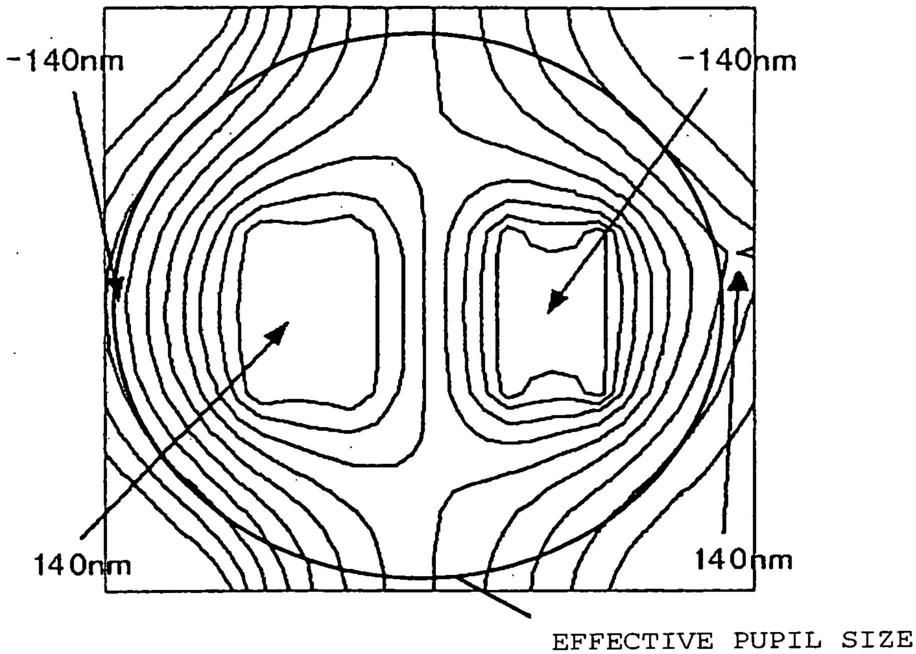
【Fig. 3】


67
SIGNAL 1
SIGNAL 2
60
64
EFFECTIVE PUPIL
61
66
SIGNAL 6
SIGNAL 5
62
65
63
SIGNAL 3
SIGNAL 4

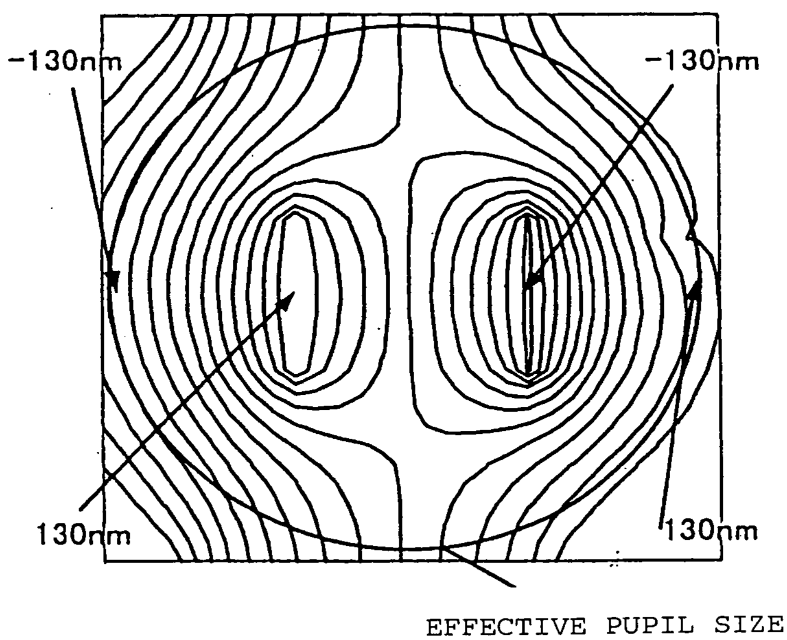
【Fig. 4】


100～200nm
-100～100nm
-200～-100nm
OBJECTIVE LENS NA: 0.6
DISC THICKNESS: 0.6 mm
DISC TILT ANGLE: 1 deg

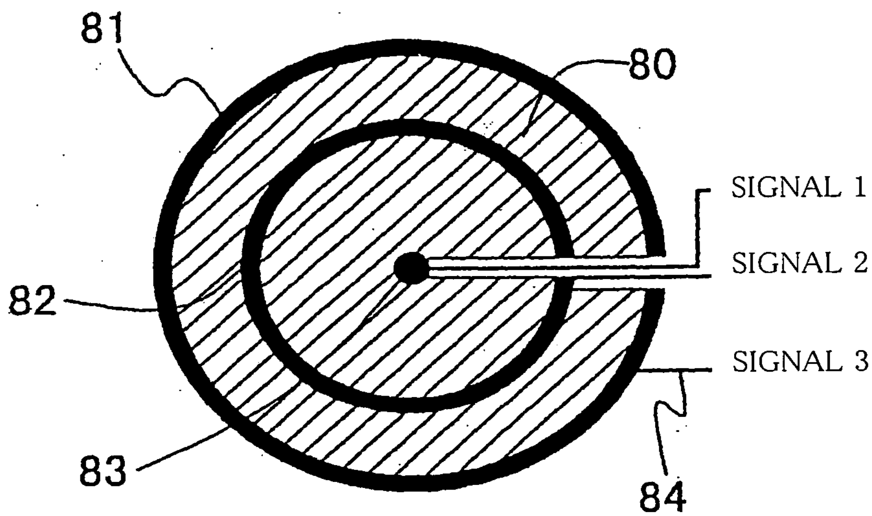
【Fig. 5】


-140nm
-140nm
140nm
140nm
EFFECTIVE PUPIL SIZE

【Fig. 6】


-130nm
-130nm
130nm
130nm
EFFECTIVE PUPIL SIZE

【Fig. 8】



【TYPE OF DOCUMENT】 ABSTRACT

【SUMMARY】

【OBJECT】

There is provided an optical head device, which includes a phase correcting element capable of continuously varying a wave front of outgoing light from a light source in a plane.

【MEANS OF SOLVING PROBLEMS】

The optical head device is configured so that a phase correcting element, wherein an anisotropic optical medium is provided between transparent substrates with two or more of power supply electrodes thereon, and wherein a voltage to be applied between opposed power supply electrodes is different in every power supply electrodes, is provided between a collimating lens 3 for collimating outgoing light from a light source 1 and an objective lens 6 for converging the outgoing light on an optical recording medium 8.

【SELECTED FIGURE】 Figure 1